Original Article

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Anatomy Section

Morphological and Morphometric Variations of Fovea Capitis Femoris: A Cross-sectional Study from Kolkata, West Bengal, India

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ABSTRACT

Introduction: The proximal end of the femur is an important anatomical modification in humans, widely explored to acquire detailed knowledge that aids in determining the exact size of hip prosthesis and minimising postoperative complications. However, thorough analysis of the various parameters of the Fovea Capitis Femoris (FCF) is frequently overlooked, yet it is also important during reconstructive surgery of the ligamentum teres femoris, radiographic evaluation of hip dysplasia, or as an anatomical landmark in hip arthroscopy. Detailed morphological and morphometric measurements of the FCF in the West Bengal population would help bridge this gap, as there are few Indian studies regarding the fovea.

Aim: To determine the morphological and morphometric measurements of the FCF in the West Bengal population.

Materials and Methods: A cross-sectional study was conducted among 297 dry femora from the Department of Anatomy at Kolkata Medical College, Kolkata, West Bengal, India from October 2023 to February 2024. The position and shape of the fovea were recorded. Morphometric measurements of the fovea (depth, transverse diameter, and vertical diameter) and the head of the femur (transverse and vertical diameters) were taken using a vernier caliper. The collected data were compiled in a Microsoft Excel sheet and analysed using Jamovi software (free version). The Pearson's correlation formula was used to determine the correlation between various parameters of the fovea and femoral head. A p-value of <0.05 was considered statistically significant.

Results: All femora had a single distinct fovea. The most frequent shape of the fovea was oval 135 (45.45%), and its most common position was in the posterior-inferior quadrant 263 (88.55%) of the femoral head. Regarding morphometric measurements, the mean values of the transverse diameter, vertical diameter, and Depth of the Fovea (DF) were 1.53±0.367 cm, 1.28±0.303 cm, and 0.304±0.141 cm, respectively. A positive correlation was found between the transverse and vertical diameters of the fovea (Pearson's correlation r=0.239), and a significant p-value (p<0.001) was also found between them.

Conclusion: Knowledge of these variations may be useful for anatomists, radiologists, anthropologists, forensic experts, and orthopaedic surgeons when planning and executing hip replacement surgeries.

Keywords: Femur head, Hip prosthesis, Measurements, Round ligament of femur

INTRODUCTION

The proximal end of the femur is an important anatomical modification in human beings, with significant clinical relevance in hip prosthesis and hip arthroplasty. To minimise postoperative complications and ensure the accurate sizing of prosthesis, the geometry of the proximal femur is a crucial parameter [1,2]. Various radiological studies have provided valuable information regarding the clinical diagnosis and surgical intervention related to the proximal end of the femur [3-5].

In addition to the various parameters of the proximal femur, the Fovea Capitis Femoris (FCF) also plays an important clinical role. It is located posterior-inferior to the center of the femoral head and is characterised by a surface depression that provides attachment for the ligamentum teres femoris [6]. Sports-related injuries to this ligament may be diagnosed presurgically by observing fractures at the site of the FCF. This ligament serves as a conduit for blood vessels (the acetabular branch of the obturator artery and the medial circumflex femoral artery) that supply the central part of the femoral head. Since, the FCF is the pathway through which blood vessels travel to supply the femoral head, it is a potential factor in the development of avascular necrosis of the femoral head [7]. Zhao K et al., revealed an association between osteonecrosis and the narrowing of nutrient foramina in the fovea [8]. Furthermore, a detailed analysis of the position of the fovea and its various measurements is required during the reconstructive surgery of the ligamentum teres femoris [9]. This anatomical knowledge is also essential for the radiographic evaluation of hip dysplasia and can serve as a landmark in hip arthroscopy [3,10].

There is a gap in the evidence regarding the most common position of the fovea, as indicated by previous studies by Perumal V et al., and Golpinar M, (posteroinferior position) [11,12], in contrast to the findings of Esra SE et al., (posterosuperior position) [7]. Methodological gaps have been noted in earlier studies concerning the morphometry and/or morphology of the fovea, which utilised calipers [13], calipers with digital software [7], and Computed Tomography (CT) images [3]. Additionally, there is a population gap in the studies conducted, as some were carried out outside India [4,11,12,14,15], while only a few were conducted within India [13,16,17]. Moreover, the Indian studies Gupta M et al., and Panda D et al., focused on the morphometry of the fovea, highlighting the need for further thorough analysis [13,17].

Therefore, the present study aimed to provide a detailed record of the morphological and morphometric measurements of the FCF (including shape, position, depth, and both transverse and vertical diameters) and the femoral head (transverse and vertical diameters) in the West Bengal population. The present research will contribute to the existing knowledge of anatomists, radiologists, and surgeons in the region and will serve as a foundation for future studies.

MATERIALS AND METHODS

A cross-sectional study was conducted on 297 dry femora in the Department of Anatomy at Medical College, Kolkata, West Bengal, India, from October 2023 to February 2024. Ethical clearance was obtained (MC/KOL/IEC/NON-SPON/2203/09/2023 dated 29.09.2023).

Inclusion criteria: Adult dry femora from both sides were selected for present study.

Exclusion criteria: Femora with diseases, surgical resections, or any distortion or breakage of the proximal end during storage were excluded from the study.

Sample size calculation: Sample size was calculated by using the formula:

$$n' = \frac{n}{1 + \frac{z^2 \times \hat{p}(1-\hat{p})}{\epsilon^2 N}}$$

Where:

Z is the z-score,

E is the margin of error,

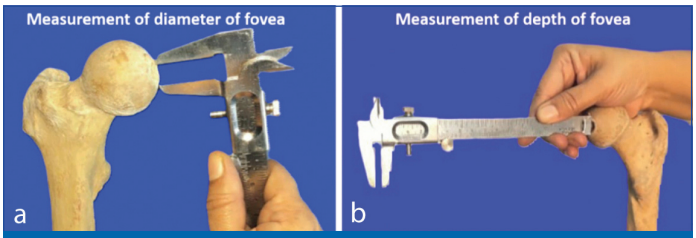
N is the population size, and

$\hat{p}$ is the population proportion.

Assuming a population proportion of 50%, a 90% level of confidence, and a margin of error of 5%, this study required a minimum sample size of 273 [18]. However, from October 2023 to February 2024, 297 dry bones were collected for the study.

Study Procedure

To determine the morphometric measurements of the fovea of the femur, the method used by Golpinar in his study was adopted in the present research [12]. A vernier caliper, calibrated up to 5 inches (12.5 cm) with an accuracy of 0.001 cm, was employed to measure all parameters of the fovea and the head of the femur [Table/Fig-1a,b].



[Table/Fig-1a,b]: Method of measurement of different parameters of Fovea Capitis Femoris (FCF).

Tools and techniques: Visual inspection and categorisation of shape were conducted according to the methodology described by Perumal V et al., for the morphologic pattern of the fovea [11]. A vernier caliper was used for the morphometric measurements of the fovea and the head of the femur.

STATISTICAL ANALYSIS

The collected data was entered into an Excel sheet and organised and summarised using descriptive statistics. It was analysed using Jamovi software (free version). Correlation was sought between various parameters of the fovea and femoral head, namely the vertical and transverse diameters of the fovea and femoral head, using the Pearson's correlation formula. A p-value of <0.05 was considered statistically significant.

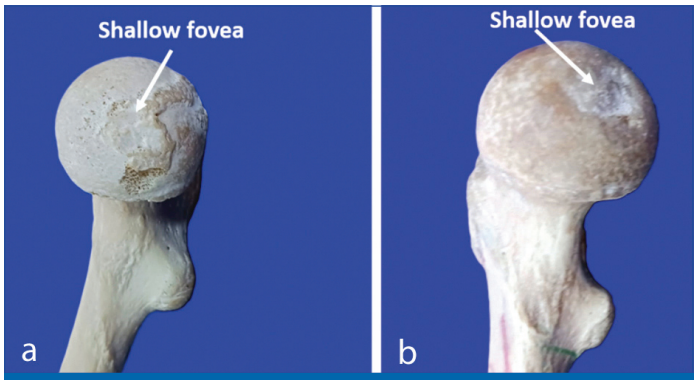
RESULTS

The mean values of the Transverse Diameter of the Fovea (TDF), Vertical Diameter of the Fovea (VDF), and Depth of the Fovea (DF) were 1.53±0.367 cm, 1.28±0.303 cm, and 0.304±0.141 cm, respectively [Table/Fig-2]. Although the total sample size was 297, DF could not be measured for 52 dry femora due to the shallowness of the fovea (DF <0.01 cm, which is the least count of the vernier caliper) [Table/Fig-3a,b]. A positive correlation was found between the transverse and vertical diameters of the fovea (Pearson's r=0.239). A negative correlation was observed between DF and both the vertical and transverse diameters of the fovea [Table/Fig-4].

The most common shape was the oval type (45.45%), while the least common shape was the irregular type (2.69%) [Table/Fig-5,6a-d]. The most common location of the fovea was found in the posteroinferior quadrant (88.55%) [Table/Fig-7,8a-e].

Descriptive statistics	Transverse Diameter of Fovea (TDF) (cm)	Vertical Diameter of Fovea (VDF) (cm)	Depth of Fovea (DF) (cm)
N	297	297	245
Missing	0	0	52
Mean	1.53	1.28	0.304
Median	1.56	1.19	0.300
Standard deviation	0.367	0.303	0.141
Variance	0.135	0.0915	0.0198
Range	2.21	1.45	0.840
Minimum	0.430	0.670	0.0600
Maximum	2.64	2.12	0.900

[Table/Fig-2]: Descriptive statistics of different measurements of Fovea Capitis Femoris (FCF).



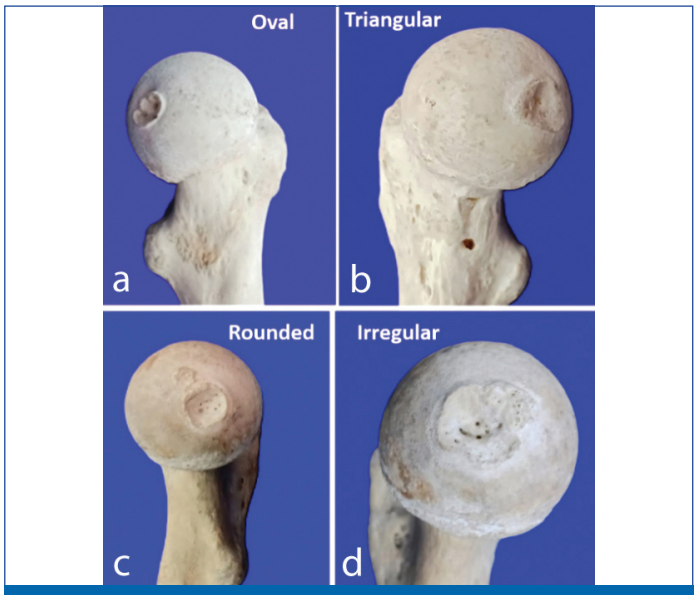
[Table/Fig-3a,b]: Images showing shallow foveal depth.

Variables		Vertical diameter of fovea (cm)	Transverse diameter of fovea (cm)	Depth of fovea (cm)
Vertical diameter of fovea (cm)	Pearson's r p-value			
Transverse diameter of fovea (cm)	Pearson's r p-value	0.239 <0.001		
Depth of fovea (cm)	Pearson's r p-value	-0.029 0.656	-0.105 0.101	

[Table/Fig-4]: Correlation matrix.

Shape of fovea	Oval	Triangular	Rounded	Irregular margin
n (%)	135 (45.45%)	78 (26.26%)	76 (25.58%)	8 (2.69%)

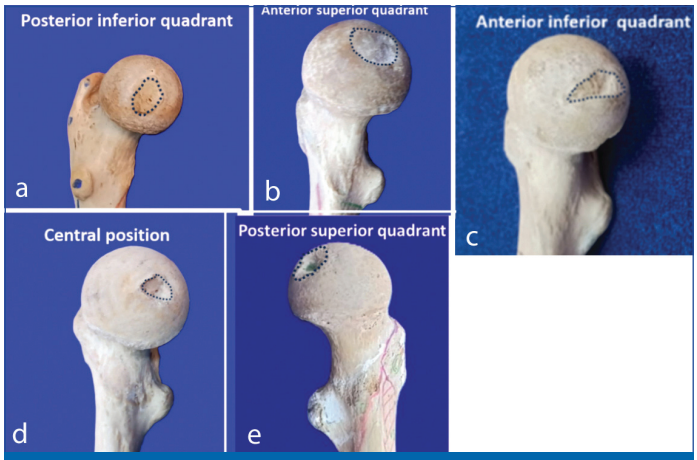
[Table/Fig-5]: Morphological variations of shape of fovea (N=297).



[Table/Fig-6a-d]: Images showing various shapes of fovea.

Position	Posterior-inferior quadrant	Central	Posterior-superior quadrant	Antero-superior quadrant	Antero-inferior quadrant
n (%)	263 (88.55%)	19 (6.39%)	5 (1.68%)	7 (2.35%)	3 (1.01%)

[Table/Fig-7]: Position of fovea in different quadrants of head of femur (N=297).



[Table/Fig-8a-e]: Images showing different positions of Fovea Capitis Femoris (FCF).

Descriptive statistics	Transverse diameter of head (cm)	Vertical diameter of head (cm)
N	297	297
Missing	0	0
Mean	4.16	4.15
Std. error mean	0.0226	0.0217
Standard deviation	0.389	0.374
Range	2.60	2.37
Minimum	3.25	3.46
Maximum	5.85	5.83

[Table/Fig-9]: Descriptive statistics for head of femur.

The mean values of the transverse diameter and vertical diameter of the head of the femur were 4.16±0.389 cm and 4.15±0.0217 cm, respectively [Table/Fig-9]. A positive correlation was found between the transverse diameter of the fovea and both the transverse diameter of the head of the femur (p-value=0.002) and the vertical diameter of the head of the femur (p-value <0.001). Additionally, a positive correlation was also observed between the transverse and vertical diameters of the head of the femur (p-value <0.001) [Table/Fig-10].

attributed to the degeneration of the perifoveal thin cartilage accompanying ageing [4]. Unlike Acar N et al., the present study failed to demonstrate any association between changes in foveal diameter and the ageing process [4]. The study by Boymans TAEJ et al., suggested a mediocaudal shift of the femoral head and neck during ageing [19]. Bertsatos A et al., stated in their article that the FCF acted as an important marker during the evaluation of hip dysplasia [15], while the studies of Beltran LS et al., and Luthra JS et al., reiterated an association between hip dysplasia and a higher position of the FCF in the femoral head [5,20]. In the Pipkin classification of femoral injuries, the type of injury (Type I and Type II) is categorised by the position of the fracture in relation to the FCF [21]. The localisation of the FCF could guide the rotational position of the femoral head during the fixation of femoral neck fractures [3,22]. The position of the fovea is an important parameter to consider during the management of patients with fractures of the proximal end of the femur. Ross JR and Gardner MJ concluded in their study that conservative treatment was acceptable in cases of fracture of the head of the femur if the reduction of the fracture fragment was achieved and the location of the fracture was below the position of the fovea [2]. In the femoral tunnel drilling technique for ligamentum teres femoris reconstruction, the channel passes through the center of the FCF [15,23]. The Hip Rotation Center (HRC) and the localisation of the FCF are important factors in determining the clinical outcome after total hip replacement [24].

Gupta M et al., studied 96 intact femora and observed a mean foveal depth of 2.95±0.75 mm, with mean foveal transverse and longitudinal diameters of 11.38±2.35 mm and 15.94±3.37 mm, respectively [13]. This observation closely resembles that of the present study; however, the mean transverse diameter of the fovea in the present study was greater than that found in the study by Golpinar M (TD=10.23±1.52 mm) [12].

In addition, the present study recorded a remarkable finding in 52 femora (17.5%), where the foveal depth could not be measured using vernier calipers due to its shallow nature. Acar N et al., also observed shallow fovea capitis (depth <2 cm) in 3.2% of examined foveae, which they termed fovea plana [4].

The most common shape of the fovea recorded in this study was oval (45.45%). This finding corroborates similar findings from many previous studies, where the most common shape was found to be oval [11,12,14]. Additionally, the present study observed an irregular shape of the fovea in 2.69% of femora, similar to the findings of Bertsatos A et al., [15].

Parameters		Vertical diameter of fovea (cm)	Transverse diameter of fovea (cm)	Depth of fovea (cm)	Transverse diameter of head (cm)	Vertical diameter of head (cm)
Transverse diameter of head (cm)	Pearson's r df p-value	0.087 295 0.135	0.182 295 0.002	0.194 243 0.002		0.917 295 <0.001
Vertical diameter of head (cm)	Pearson's r df p-value	0.108 295 0.062	0.209 295 <0.001	0.166 243 0.009	0.917 295 <0.001	

[Table/Fig-10]: Correlation matrix.

DISCUSSION

The FCF provides an attachment for the ligamentum teres femoris, through which blood vessels reach the center of the head of the femur and supply it. This was reiterated by the study of Perumal V et al., who observed several vascular foramina at the site of attachment of the ligamentum teres femoris, which conveyed vessels to supply the central part of the head of the femur. Such findings highlight the clinical importance of the FCF [11].

Previous studies regarding the morphometry of the FCF and its position in the hip joint have revealed several surgical and clinical implications. In their study, Acar N et al., observed that the diameter of the fovea increased with the ageing process, which might be

Like the studies by Perumal V et al., Golpinar M, Yarar B et al., [11,12,14], the present study revealed that the most common position of the fovea with respect to the femoral head is in the Posteroinferior quadrant. This contrasts with the study by Esra SE et al., where the most common position was found to be the posterosuperior quadrant [7].

In the present study, the mean values of the transverse and vertical diameters of the head of the femur were found to be 4.16±0.389 cm and 4.15±0.0217 cm, respectively. These values were less than those found in the study by Chowdhury MS et al., where the transverse and vertical diameters of the head of the femora were 5.82±0.19 cm and 5.84±0.42 cm in males, and 4.21±0.20 cm

Parameters	Perumal V et al., (2017) New Zealand [11]	Yarar B et al., (2020) France [14]	Golpinar M (2022) Turkey [12]	Gupta M et al., (2022) India (Uttar Pradesh) [13]	Present study (2024) India (West Bengal)
Sample size (N)	125	146	57	96	297
Shape of fovea	Oval in 66%, circular in 28%, and triangular in 6%.	The most common type- oval	Oval 43.8%, round 40.4%, triangular 10.5%, and piriform shape types 5.3%	-	Oval-45.45%, Triangular-26.26%, Rounded-25.58%, and Irregular margin-2.69%
Location of fovea	Located on the postero-inferior quadrant of the femoral head	Type 2 localisation was the most common location	Postero-inferior localisation was commonest one	-	The most common location was Posterior-inferior quadrant- 88.55%
Transverse diameter of fovea (mean value)	1.3±0.32 cm	Sizes were smaller in type -1 localisation	10.23±1.52 mm	11.38±2.35 mm	1.53±0.367 cm
Vertical diameter of fovea (mean value)	1.77±0.4 cm	Sizes were smaller in type-1 localisation	15.01±2.13 mm	15.94±3.37 mm	1.28±0.303 cm
Depth of Fovea (DF) (mean value)	-	-	2.71±1.09 mm	2.95±0.75 mm	0.304±0.14 cm

[Table/Fig-11]: Comparison of present study with previous similar studies in other settings and regions [11-14].

and 4.06±0.18 cm in females, respectively [25]. Their study also revealed sexual variations in the morphometric measurements of the proximal end of the femur. Similar to the present study, the studies by Verma M et al., and Iyem C et al., reported mean values of femoral head diameter to be 42.32±4.11 mm and 48.1±3.7 mm, respectively [16,26].

Contractor JB et al., conducted a study on 94 dry femora in Indian population and revealed the significant variation of different parameters in proximal end of femur and importance of considering racial diversity during selection of implants in total hip arthroplasty for improving the longevity of this procedure [27].

Zhao K et al., proved in their study that defective nutrient foramina might be an indicator of Osteonecrosis of the Femoral Head (ONFH) [8]. Mukhia R et al., studied a total of 75 femora from the Nepalese population and recorded a mean diameter of 13.05±0.9 cm for the femoral head [28]. The results of their study reflected differences in the morphometry of the femoral head among populations in other countries, including the present study population. Additionally, Verma M et al., stated in their study that European data-based prosthesis were mismatched for Indians [16]. The exact size of the prosthesis could be determined from established data from the Indian population. Similar previous studies have observed that morphometric measurements of the femoral head are important for obtaining the accurate size of the prosthesis [29,30]. An overview of the different parameters of the femoral head and fovea in the present study, comparing them with other studies conducted in India and international datasets has been depicted in [Table/Fig-11] [11-14]. This table highlights the differences in various parameters of the fovea and the femoral head.

Limitation(s)

Although the present study had a sample size of 297, the shallow Depth of Fovea (DF) (<0.01 cm) in 52 femora could not be measured with vernier calipers, which presents a major limitation. Additionally, since this study was conducted at a medical college in Kolkata, West Bengal, it may not be representative of the entire Indian population. Therefore, it is recommended that multicentric studies with larger sample sizes be conducted in the future to establish standardised national values.

CONCLUSION(S)

A detailed study of the morphology and morphometry of the FCF in the West Bengal population revealed that the most common shape of the fovea is oval, and its most frequent position is in the posterior-inferior quadrant of the femoral head. The mean values for the transverse diameter, vertical diameter, and DF were found to be 1.53±0.367 cm, 1.28±0.303 cm, and 0.304±0.141 cm, respectively. This data will contribute to the existing knowledge of anatomists, radiologists, and surgeons and may be useful in the planning and execution of surgical interventions involving the proximal end of the femur.

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